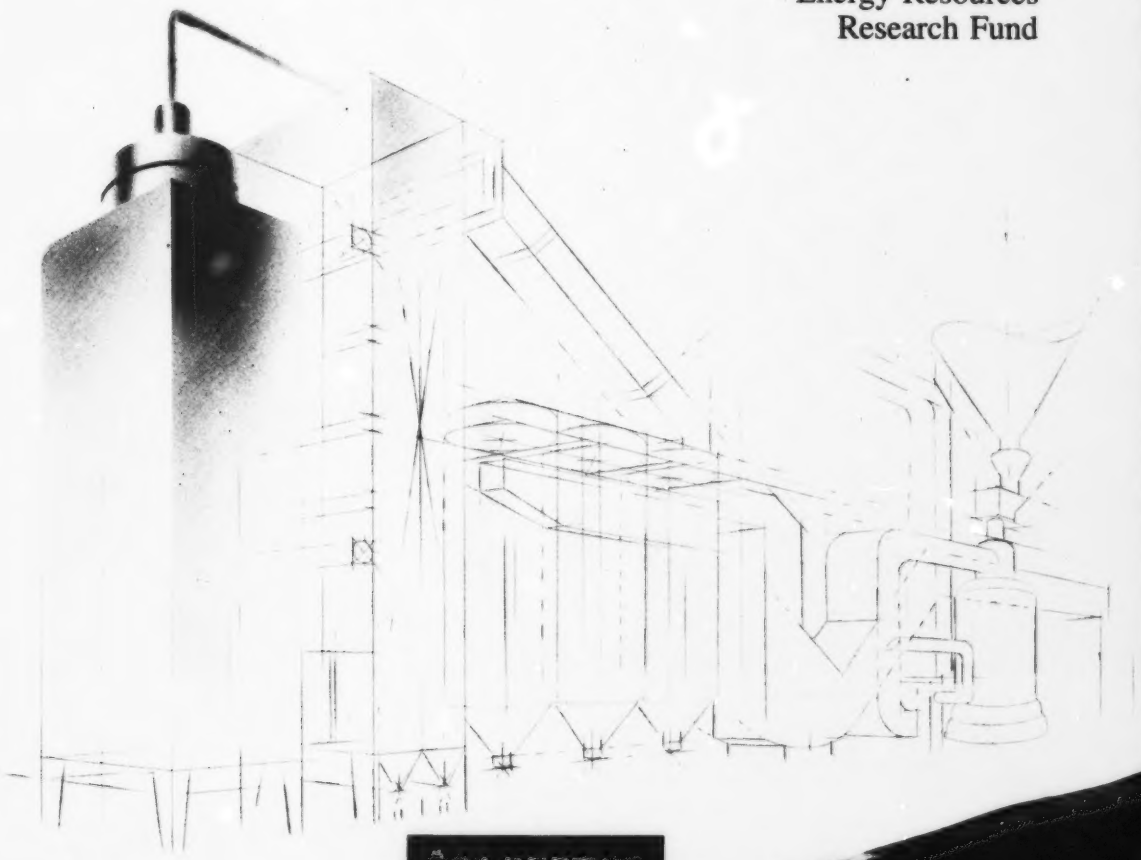
Alberta

Scientific
and Engineering
Services

Development of a Coal-Fired Boiler for Steam Injection in Heavy Oil Recovery

Projects supported in part
by the Alberta/Canada
Energy Resources
Research Fund



ALBERTA
OFFICE OF
COAL
RESEARCH

Development of a Coal-Fired Boiler for Steam Injection in Heavy Oil Recovery

Projects supported in part
by the Alberta/Canada
Energy Resources
Research Fund

1989
Edmonton

Alberta
ENERGY
Scientific and Engineering
Services and Research Division

90-01018/

Pub. No. I/293

ISBN 0-86499-638-1

Disclaimer

The contents of this publication are based on the information and data obtained from, and the results and conclusions of, research projects conducted by independent researchers with financial assistance from the Alberta/Canada Energy Resources Research Fund.

The contents of this publication do not necessarily reflect the views of the Government of Alberta, its officers, employees or agents or of the Alberta/Canada Energy Resources Research Fund Committee.

Neither the Government of Alberta nor its officers, employees or agents makes any warranty, express or implied, representation or otherwise, in respect of, or assumes any liability for, the contents of this publication.

Foreword

Since 1976, numerous projects have been initiated in Alberta by industry and by academic research institutions which are aimed at better utilization of Alberta's energy resources.

These research, development and demonstration efforts were funded by the Alberta/Canada Energy Resources Research Fund (A/CERRF), which was established as a result of the 1974 agreement on oil prices between the federal government and the producing provinces.

Responsibility for applying and administering the fund rests with the A/CERRF Committee, made up of senior Alberta and federal government officials.

A/CERRF program priorities have focused on coal and conventional energy resources, as well as energy conservation and renewable energy. Program administration is provided by staff within the Scientific and Engineering Services and Research Division of Alberta Energy.

In recognition of the importance of coal to Alberta's economy, the Alberta Office of Coal Research and Technology was established in 1984 within Alberta Energy and Natural Resources (now Alberta Energy). Its primary purpose is to encourage the development and application of new technologies related to Alberta coals. The Office provides funding contributions to research and development projects in industry, academic institutions and other research establishments and monitors their progress in an overall program of improving the production, transportation and marketability of Alberta coals.

In order to make research results available to industry and others who can use the information, highlights of studies are reported in a series of technology transfer booklets. For more information about other publications in the series, please refer to pages eight and nine.

Development of a Coal-Fired Boiler for Steam Injection in Heavy Oil Recovery

In 1985/86, the Alberta Office of Coal Research and Technology, along with seven resource companies and the Canada Centre for Mineral and Energy Technology (CANMET), financed a study entitled Fuel Options for Enhanced Hydrocarbon Recovery. The investigation, carried out by L.A. Smith Consulting & Development Ltd. of Calgary, concluded that it was cost-effective for oil companies to use coal instead of natural gas to generate steam needed for enhanced recovery of heavy oil. In fact, the study showed that more coal might eventually be needed for this purpose than is now used to generate electricity in Alberta. This implies a potentially major expansion of Alberta's subbituminous mining operations.

The study also noted that to use coal successfully in heavy oil recovery schemes, a specially designed, pulverized coal-fired boiler was needed.

Subsequently, the Coal-Fired Steam Generation for Heavy Oil Recovery Technical Committee[1] (formerly known as the Coal Use for Enhanced Oil Recovery Technical Committee) was formed[2]. It proposed a four-stage development program as the next step in using coal for heavy oil recovery. In the first stage of that program, in a project directed by Luscar Ltd., boiler manufacturers were asked to propose designs for an innovative coal-fired steam generator. They were informed that the boiler would use pulverized coal, the boiler feedwater would contain a high total dissolved solids concentration, the steam generation capacity should be 25 to 50 kg/s (180 000 to 200 000 lb./hr.), and modular construction was required to allow truck transportation to field production sites.

Proposals received from two companies were regarded as approximately equal. One, from Combustion Engineering Canada Inc., proposed to burn coal which had been pulverized so that 70 per cent of the particles passed through a 200 mesh (74 micron) screen. The other proposal, submitted by Struthers-TIW Ltd., involved combustion of micronized coal, a concept new to Alberta. It would burn coal which was pulverized to allow 90 per cent of the particles to pass through a 325 mesh (43 micron) screen.

It was decided that both combustion systems looked promising. Consequently, the technical committee decided it would support development of Combustion Engineering Canada Inc. technology, while one of the Committee members (Esso Resources Canada Limited) would also continue to investigate the Struthers-TIW system. Subsequently, Fording Coal Limited, on behalf of the technical committee, asked Combustion Engineering Canada Inc. to proceed with engineering designs.

Meanwhile, Esso Resources Canada Limited, also on behalf of the technical committee, contracted Monenco Consultants Limited of Calgary to undertake a study of emission control options applicable to the boiler systems being designed. Also, a feasibility study was made of the Low NO_x/SO_x Burner (LNSB) to burn coal in an enhanced heavy oil application. This burner is under development by TransAlta Resources Investment Corporation of Calgary. Finally, sorbent injection was studied as a method for in-furnace emission control.

These studies were funded in part by the Alberta/Canada Energy Resources Research Fund (A/CERRF), as administered by the Alberta Office of Coal Research and Technology. The results are described here.

---

[1]Initial corporate participants were: Esso Resources Canada Limited, Fording Coal Limited, Luscar Ltd., Obed Mountain Coal Company Limited and TransAlta Utilities Corporation.

[2]Committee members on July 31, 1989 were: Esso Resources Canada Limited, Fording Coal Limited, Luscar Ltd., TransAlta Utilities Corporation, Alberta Power Limited, Shell Canada Limited, Unocal Canada Limited, Alberta Office of Coal Research and Technology, and other observers. Delta Projects Inc. provided co-ordination and promotional services to the committee.

Coal-Fired Steam Injection Boiler

Fording Coal Limited, on behalf of the Coal-Fired Steam Generation for Heavy Oil Recovery Technical Committee[3], contracted Combustion Engineering Canada Inc. to proceed with a design and cost study for a 190 GJ/h (180 million BTU/hr.) pulverized coal-fired boiler suitable for use in heavy oil recovery operations.

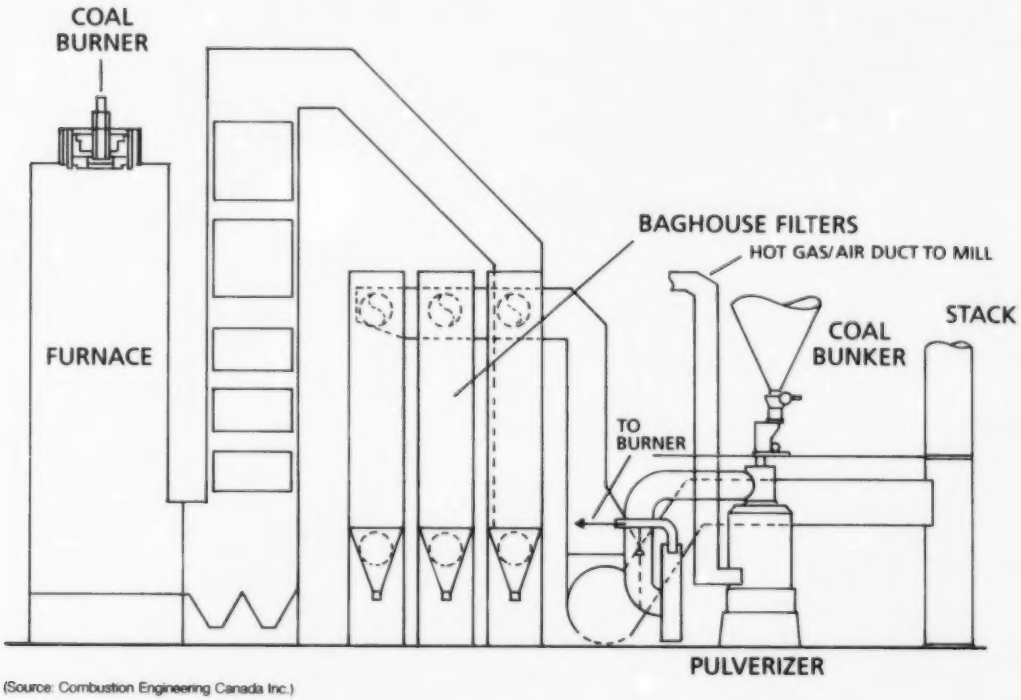
A vertical, down-fired, three-pass prototype steam generator was designed to be used with a particular range of coal properties. It is expected to satisfy technical requirements for an oil field unit operating at Cold Lake, Alberta and fired with the "design" coals.

The design includes furnace sorbent injection technology capable of absorbing approximately 40 per cent of the sulphur present in the design coals and reducing the level of sulphur dioxide (SO_2) emissions to satisfy current federal guidelines for utility boilers. Also, the firing system and dust collection equipment were designed to satisfy existing guidelines for nitrogen oxides (NO_x) and particulates, respectively. The use of primary air dilution, staged air admission and low peak flame temperatures is expected to result in NO_x levels that are one-half the existing federal guidelines.

Specific design details are available only to project participants at this time.

[3]Other committee members who provided funding for this design study were: Luscar Ltd., Esso Resources Canada Limited, TransAlta Utilities Corporation and Alberta Power Limited, in addition to the Alberta Office of Coal Research and Technology.

Side Elevation of Proposed Coal-Fired Boiler



(Source: Combustion Engineering Canada Inc.)

Emission Control Technology

The sulphur content of some Alberta subbituminous coals is sufficiently low that current, new-source emission regulations can be met without sulphur oxide emission control. However, for most Alberta subbituminous coals, some degree of flue gas clean-up or control will be required. If coal-fired boilers are to be used in the future at in situ heavy oil recovery operations, they must be capable at least of satisfying existing regulations and meeting even more stringent guidelines that might be introduced for SO_x and NO_x emissions.

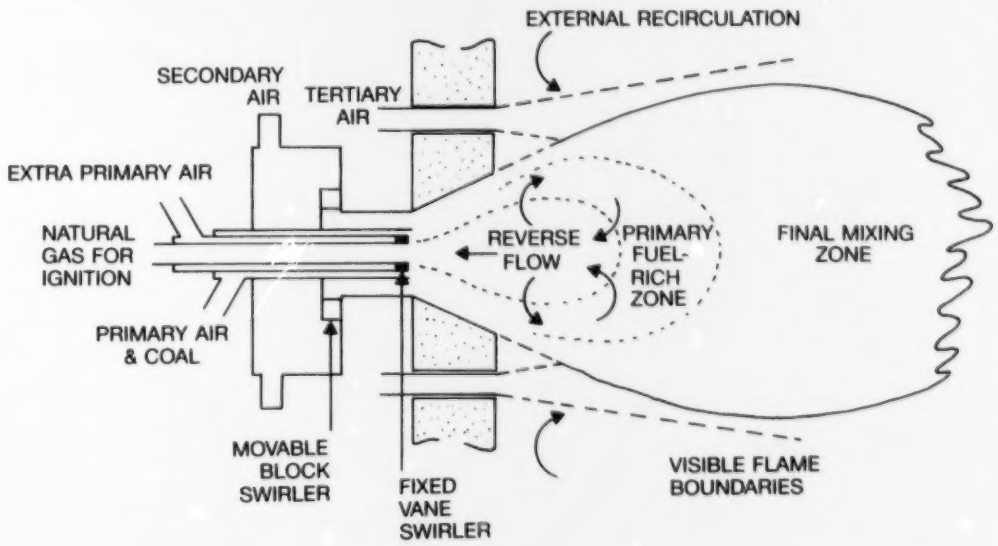
Therefore, a project was undertaken to identify appropriate NO_x and SO_x emission control technologies that could be incorporated into the coal-fired boilers being designed for in situ heavy oil recovery.

The investigation, directed by Esso Resources Canada Limited on behalf of the Coal-Fired Steam Generation for Heavy Oil Recovery Technical Committee, and subcontracted to Monenco Consultants Limited of Calgary, involved an evaluation of in-furnace and post-combustion emission control technologies. The in-furnace technologies were: furnace sorbent injection; multi-stage burners; fuel staging; advanced external combustors, including slagging combustors; and non-selective catalytic reduction. The post-combustion control technologies were: selective catalytic reduction; duct sorbent injection; calcium injection; lime spray drying; wet limestone and lime scrubbing; and dual alkali.

It was concluded that the most cost-effective approach to emission control would be to use in-furnace technology as much as possible, and supplement it with post-combustion control if emission standards become even more stringent in the future.

For the present, it was recommended that a combination of furnace sorbent injection and multi-stage burners be used. Several add-on technologies were suggested in the event of more stringent standards.

Schematic of Typical Multi-Staged Burner



(Source: Coal for Enhanced Oil Recovery, Emission Controls Study, Esso Resources Canada Limited, 1988)

Sorbent Injection Technical Committee

Following completion of the emission control study, the Sorbent Injection Technical Committee[4] was established to pursue investigations involving the injection of alkali metal sorbents into coal-fired furnaces. This is done to capture acid-forming gases in the form of easily extracted particulates. The committee's principal objective is to establish whether sorbent injection is viable for sulphur gas emission control in Alberta.

Sorbent Injection Study

Although the plains coals of western Canada are generally low in sulphur, with contents ranging from 0.2 to 0.6 per cent by weight, coals from some reserves contain sufficient sulphur to exceed emission guidelines for sulphur dioxide (SO_2) when they are burned in conventional furnaces. Currently, these limits are 258 ng/J (0.6 lb./million BTU), but may be reduced in the future.

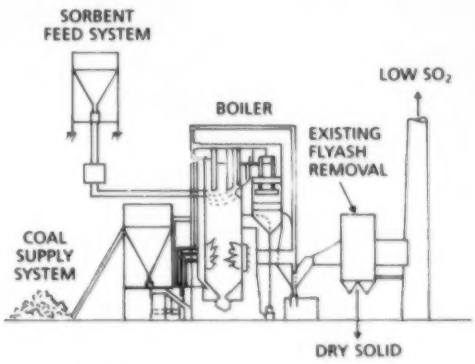
One cost-effective method for achieving modest levels of SO_2 control is to inject a finely ground sorbent into the furnace. For example, lime or limestone has been used for this purpose. Experience elsewhere in North America and Europe has shown that 50 per cent of the sulphur present in coal can be captured in this manner. The effectiveness of this technique with low-sulphur Alberta coals has not been demonstrated, however.

Consequently, in a study co-ordinated by Alberta Power Limited on behalf of some members of the Sorbent Injection Committee[5], the state-of-the-art of sorbent injection was reviewed and summarized in detail, and assessments were made as to the likely capture of sulphur when Alberta coals are used.

From a limited amount of testing done in Saskatchewan, it was concluded that sulphur capture from coals having sulphur contents of approximately 0.5 per cent should range from 14 to 49 per cent. The Saskatchewan studies showed that use of hydrated lime produced better results than with limestone.

It was concluded that sorbent injection techniques have some potential for low-cost SO_2 reduction when used at existing power plants. It was recommended that bench-scale tests of Alberta coals and locally available sorbents should be undertaken to determine the best combinations for Alberta's coal-fired electricity-generating plants.

Sorbent Injection



(Source: Energy and Environmental Research Corporation)

Low NO_x/SO_x Burner

The Low NO_x/SO_x Burner is a multi-stage, slagging-type combustor intended to control NO_x and SO_x simultaneously. It was developed by Rockwell International in the United States, but the technology is now owned by TransAlta Resources Investment Corporation of Calgary. Pilot plant testing at 17.9 GJ/h (17 million BTU/hr.) has confirmed the design concept for the LNSB and verified that the advanced combustion concepts of the LNSB can be used in a cost-effective manner to reduce SO_x emissions from the combustion of subbituminous coal by 70 per cent at least. Also, the device suppresses NO_x emissions to less than 100 parts per million (ppm), while achieving 100 per cent burnout of carbon monoxide and 95-99 per cent overall carbon burnout.

Preliminary studies indicate that the capital cost of equipping coal-fired boilers with LNSBs should be a small fraction of the cost to obtain similar NO_x and SO_x control with state-of-the-art flue gas treatment systems. Also, operating costs should be greatly reduced. Furthermore, incorporation of a slag separator provides the opportunity for retrofit conversion of oil- or gas-fired boilers to coal firing.

[4]Committee members on July 31, 1989 were: Esso Resources Canada Limited, Edmonton Power, TransAlta Utilities Corporation, Alberta Power Limited, Luscar Ltd. and the Alberta Office of Coal Research and Technology.

[5]Additional funding was provided by: Edmonton Power, Esso Resources Canada Limited, TransAlta Utilities Corporation and the Alberta Office of Coal Research and Technology.

In 1986/87, the Alberta Office of Coal Research and Technology provided some financial assistance to complete the pilot-plant tests and to prepare the detailed design of a 105.4 GJ/h (100 million BTU/hr.) commercial-scale demonstration unit.

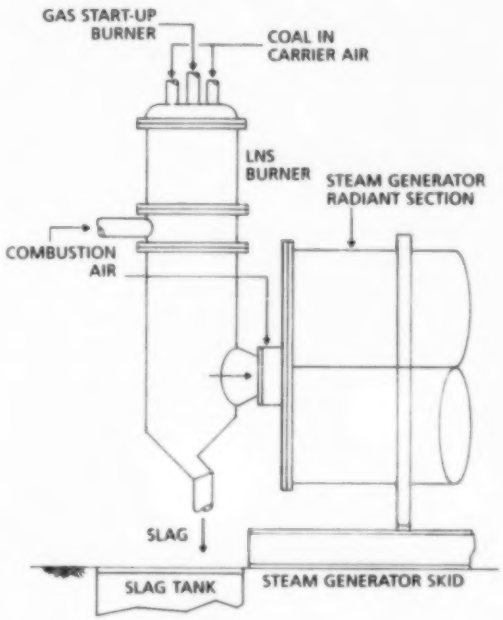
Application of the LNSB to an Oil Field Steam Generator

Following the establishment of the Coal-Fired Steam Generation for Heavy Oil Recovery Technical Committee, it was suggested that the Low NO_x/SO_x Burner might be ideal for oil field applications, particularly because the burner can be retrofitted to current gas-fired steam generators. This represents an alternative to designing an all-new, coal-fired boiler. Therefore, a study was initiated[6] to determine the feasibility of installing a LNSB on an existing 52.7 GJ/h (50 million BTU/hr.) steam generator. It would be required to burn low-ash, low-sulphur subbituminous coal, and must also be capable of being scaled up for use on current, commercial-scale heavy oil recovery plants rated at 189.7 GJ/h (180 million BTU/hr.).

In preparing the design for the enhanced heavy oil recovery application, it was assumed that subbituminous coal used as fuel would have a heating value of 33 237 kJ/kg (7 731 BTU/lb.), 25 per cent moisture, 11.5 per cent ash and a sulphur content of 0.36 per cent. Assuming the uncontrolled SO_2 emissions would be 400 ng/J (0.93 lb./million BTU), a 70 per cent reduction would amount to 120 ng/J (0.28 lb./million BTU). Therefore, the target emission level for the design was set at 128 ng/J (0.3 lb./million BTU). This is one-half the current level designated in Canadian regulations for emissions from either coal-fired or gas-fired burners. Similarly, the target set for NO_x emissions was 86 ng/J (0.2 lb./million BTU). This is one-third the existing regulated level for coal-fired burners and equals the level established for gas-fired burners.

The study resulted in the preparation of demonstration-scale and commercial-scale designs to allow the LNSB to be used with horizontal, once-through steam generators. It was concluded that these designs can reduce emissions to levels well below current Alberta and Canadian objectives for coal-fired steam generators.

Low NO_x/SO_x Burner/Steam Generator Assembly



(Source: LNS Burner on EOR Steam Generator Feasibility Study, TransAlta Resources Investment Corporation, 1988)

[6]Funding for this project was provided by: TransAlta Resources Investment Corporation, Esso Resources Canada Limited, Shell Canada Limited and the Alberta Office of Coal Research and Technology.

NO_x/SO_2 Emission Regulations and Program Goals for Low NO_x/SO_x Burner Demonstration

	SO_2 lb./MBtu (ng/J)		NO_x lb./MBtu (ng/J)	
	Current Regulations	Program Goals	Current Regulations	Program Goals
Coal	0.6 (258)	0.3 (129)	0.6 (258)	0.2 (86)
Gas	0.6 (258)	N/A	0.2 (86)	N/A

(Source: LNS Burner on EOR Steam Generator Feasibility Study, TransAlta Resources Investment Corporation, 1988)

LNSB Steam Generator Demonstration

Based on the design and cost information obtained during the LNSB feasibility study, a three-year project was initiated in 1988/89 by TransAlta Resources Investment Corporation to demonstrate the LNSB at an Esso Resources Canada Limited heavy oil operation near Cold Lake.

The principal objectives of the project are to demonstrate:

- the ability to burn coal in an existing heavy oil recovery steam generator using the LNSB. A stand-alone, 52.7 GJ/h (50 million BTU/hr.) steam generator will be built for this purpose;
- the capability of the LNSB to control SO_2 and NO_x emissions to satisfactory levels while firing Alberta subbituminous coals at a commercial scale under regular operating conditions;
- the reliability and durability of auxiliary systems operating with the burner and steam generator; and
- the capability of the LNSB to fire natural gas for a short duration in the event of a temporary interruption in coal availability.

Future Plans

Subsequent phases of research planned by the Coal-Fired Steam Generation for Heavy Oil Recovery Technical Committee will include some fuel testing, during which a range of Alberta coals will be tested to allow combustion performance and emission generation to be predicted when these coals are burned in the boilers being investigated.

Also, alternative coal transportation and handling methods are to be evaluated to achieve the best conditions of economics and logistics, with minimum environmental disruption.

Results from the fuel-testing component should allow bottom ash and fly ash characteristics to be predicted. This will lead to an evaluation of ash disposal/use alternatives.

The prototype unit being designed for this program will be located and tested in the field. Its exact location will be decided later.

As required, the general public, as well as coal companies and the petroleum industry, will be kept informed as the program progresses.

Coal companies, oil firms and other interested parties are invited to participate in the various project phases to obtain access to the technology. A publication produced by the Alberta Office of Coal Research and Technology, entitled Opportunities to Use Coal in Enhanced Oil Recovery, describes some of the early work in this program. It is available from the Alberta Energy/Forestry, Lands and Wildlife Information Centres; see page eight.

Persons wishing to participate on the Coal-Fired Steam Generation for Heavy Oil Recovery Technical Committee, should contact:

Chairman
Alberta Office of Coal Research and Technology
Alberta Energy
3rd Floor, Blue Cross Place
10009 - 108 Street
Edmonton, Alberta
T5J 3C5
Telephone: (403) 427-8042
Telex: 037-3676
Fax: (403) 422-0975

Contacts

Non-confidential information about the coal-fired steam injection boiler is available from:

C.J. McKenny
Chief Geologist
Fording Coal Limited
#200, 205 Ninth Avenue S.E.
Calgary, Alberta
T2G 0R4

Telephone: (403) 264-1063

More information about the study of emission control technologies is available from:

D.E. Weckman
Oil Sands and Coal Department
Esso Resources Canada Limited
237 Fourth Avenue S.W.
Calgary, Alberta
T2P 0H6

Telephone: (403) 237-3737

Specifics regarding the state-of-the-art of sorbent injection are available from:

D.P. Deshpande
Supervising Engineer, Chemical and Combustion
Alberta Power Limited
10035 - 105 Street
Edmonton, Alberta
T5J 2V6

Telephone: (403) 420-7310

For more information about the Low NO_x/SO_x Burner, contact:

G.D. Bateson
Executive Assistant
TransAlta Utilities Corporation
110 - 12th Avenue S.W.
Box 1900
Calgary, Alberta
T2P 2M1

Telephone: (403) 267-7110

Additional copies of this publication are available from:

Information Centre
Alberta Energy/Forestry,
Lands and Wildlife
Main Floor, Bramalea Bldg.
9920 - 108 Street
Edmonton, Alberta
T5K 2M4

Telephone: (403) 427-3590

Information Centre
Alberta Energy/Forestry,
Lands and Wildlife
Main Floor, Britannia Bldg.
703 - 6th Avenue S.W.
Calgary, Alberta
T2P 0T9

Telephone: (403) 297-6324

For more information about A/CERRF, contact:

Senior Manager,
Technology Development
Scientific and Engineering Services and
Research Division
Alberta Energy
3rd Floor, Blue Cross Place
10009 - 108 Street
Edmonton, Alberta
T5J 3C5

Telephone: (403) 427-8042
Telex: 037-3676
Fax: (403) 422-0975

More can be learned about the Alberta Office of Coal Research and Technology by contacting:

Chairman
Alberta Office of Coal Research and Technology
Alberta Energy
3rd Floor, Blue Cross Place
10009 - 108 Street
Edmonton, Alberta
T5J 3C5

Telephone: (403) 427-8042
Telex: 037-3676
Fax: (403) 422-0975

Other publications in this series that deal with coal research include:

An Economic Analysis of Coal Pipeline Systems, 6 pages, January 1987. (Out of print)

Opportunities to Use Coal in Enhanced Oil Recovery, 8 pages, April 1988.

Development of an Agglomeration Process to Beneficiate and Transport Alberta Coals, 14 pages, June 1988.

Gasification of Western Canadian Coals, 14 pages, June 1988.

Coal Research Centre, Devon, 10 pages, August 1988.

Co-processing Studies of Alberta Subbituminous Coals, 14 pages, December 1988.

Mathematical Modelling of Automedium Cyclones, 10 pages, January 1989.

The Technical Committee Approach to Coal Research, 6 pages, January 1989.

Advanced Coal Mining Techniques for Alberta, 10 pages, March 1989.

Some Combustion Studies of Alberta Coals, 13 pages, May 1989.

Gasification of Alberta Coals, 10 pages, June 1989.

Development of Clean Coal Technologies for Alberta, 12 pages, July 1989.

Coal Preparation Research in Alberta, 22 pages, September 1989.